

Occupational Risk Factors for Cancer of the Central Nervous System: A Case-Control Study on Death Certificates From 24 U.S. States

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The risk of cancer of the central nervous system (CNS) by industry and occupation was investigated with a case-control analysis of the death certificates of 28,416 cases and 113,664 controls, selected from over 4.5 million deaths in 24 U.S. states between 1984 and 1992. Industries showing consistent increases in risk by gender and race included textile mills, paper mills, printing and publishing industries, petroleum refining, motor vehicles manufacturing, telephone and electric utilities, department stores, health care services, elementary and secondary schools, and colleges and universities. CNS cancer risk was increased for administrators in education and related fields, secondary school teachers, and other education- and health-related occupations. The application of job-exposure matrices to the industry/occupation combinations revealed a modest increase in risk for potential contact with the public at work and exposure to solvents. Occupational exposure to electromagnetic fields (EMF) was not associated with CNS cancer, although an association was observed with a few EMF-related occupations and industries. Agricultural exposures were associated with significant risk increases among white women and white men. Further work is required to investigate in more detail specific occupational exposures or possible confounders responsible for the observed associations. Am. J. Ind. Med. 33:247-255, 1998. © 1998 Wiley-Liss, Inc.

KEY WORDS: neoplasms; socio-economic status; occupation; industry; epidemiology; job-exposure matrices

INTRODUCTION

Epidemiologic studies of central nervous system (CNS) tumors have found excesses among the upper social class [Pearce and Howard, 1986], and among professionals, white-collar workers, and health related occupations [Ahlbom et al., 1986; Hall et al., 1991; Mallin, 1989; McLaughlin, 1987; Reif, 1989a; Stroup et al., 1989; Thomas et al., 1986; Walrath and Fraumeni, 1984; Wang et al., 1988].

However, it is unclear whether these excesses are due to better access to medical care, and hence more accurate diagnostic procedures [Finkelstein and Liss, 1987] or to some other lifestyle factor. On the other hand, workplace exposures have been suggested to play a role in brain cancer etiology by reports of risk increases among farmers [Blair et al., 1992; Preston et al., 1982; Reif, 1989b], rubber workers [Monson and Fine, 1978; Thomas and Waxweiler, 1986], petrochemical workers [Thomas and Waxweiler, 1986], vinyl chloride production workers [Tabershaw and Gaffey, 1974], and in occupations involving exposure to chlorinated hydrocarbons [Heineman et al., 1994], electromagnetic fields [Lin and Dischinger, 1985], and lead [Anttila et al., 1996].

To explore further the association of occupational risk factors and brain cancer covering also less frequently held jobs, we used a large data set of death certificates from 24 U.S. states, in which industry and occupation were coded, to

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TABLE I. Distribution by Race and Gender of Deaths from Cancer of the Central Nervous System and Controls and Average Age at Death (Standard Deviation) in Study of Death Certificates in 24 U.S. States, 1984–1992

	Total		Cases		Controls	
	No.	Age at death	No.	Age at death	No.	Age at death
African-American women	3,230	62.0 (15.5)	646	62.0 (15.3)	2,584	62.0 (15.5)
African-American men	3,780	58.3 (15.0)	756	58.3 (14.9)	3,024	58.3 (15.0)
White women	61,670	64.3 (14.7)	12,334	64.1 (14.4)	49,336	64.3 (14.7)
White men	73,400	61.2 (14.2)	14,680	61.1 (14.1)	58,720	61.2 (14.2)

calculate risks of brain cancer by occupation, industry, and specific workplace exposures among men and women, and among whites and African-Americans.

METHODS

Since 1984, the National Cancer Institute, the National Institute for Occupational Safety and Health, and the National Center for Health Statistics have supported the coding of occupation and industry titles on death certificates from a number of U.S. states. This resource was developed as a tool for national surveillance of occupational disease. Mortality records from 24 states among subjects aged 25 years or more, covering the years 1984 to 1992 and providing a total of over 4.5 million death certificates, were used to evaluate CNS cancer risks by occupation and industry. Only one occupation and industry rather than a work history is reported on the death certificates, and no measure of duration of employment is available. Cases were 28,416 subjects who died from cancer of the brain (ICD-9 code 191 = 27,784/28,416; 97.8%) and other parts of the central nervous system (ICD-9 code 192 = 632/28,416; 2.2%). Excluding CNS cancers other than the brain from analysis did not modify the risk estimates. Also, because of diagnostic inaccuracy in the death certificates and the small proportion of these cancers over the total number of cases, we did not consider such an exclusion as useful in significantly improving diagnostic accuracy. For each case, four controls, frequency-matched by state, race, gender, and 5-year age-group, were selected among subjects who died from nonmalignant diseases, excluding neurological disorders. Race groups were “African-Americans” and “whites.” Subjects of Asian origin were not considered for analysis, as they were too few in the whole data set.

To evaluate risks by likely exposure to potential occupational risk factors for CNS cancer, an experienced industrial hygienist (MD) and an occupational physician (PC) developed *a priori* job-exposure matrices for electromagnetic fields, solvents, herbicides, other pesticides, contact with the public, contact with animals, and lead based on three-digit occupation and industry codes from the 1980 Census of

Population [Bureau of the Census, 1982]. A binary (yes/not) exposure code for each risk factor was assigned to every three-digit occupation and industry Census code, based upon literature information [Zenz, 1988], computerized exposure data bases (OSHA files, NIOSH inspections data-base), and personal experience of the same professionals. Occupations were divided into three groups: exposed, unexposed, and a third group for which assessment of the potential for each exposure was not possible based on the occupational title alone. For subjects with these occupations, the exposure assessment was based on the industry code. Therefore, the application of the matrices to the individual combinations of occupation and industry resulted in a binary assessment (exposed/ unexposed) for each of the seven workplace hazards. We herein refer results for six job-exposure matrices. The association with lead was discussed in a separate report [Cocco et al., manuscript submitted for publication].

Race/gender specific odds ratios (ORs) were calculated with logistic regression for each occupation and industry with at least 18 subjects (including cases and controls) or at least three cases, and for the six workplace exposures. When a significant risk increase for a given occupation or industry was observed in a study group, risk for the same occupation or industry in the other study groups was calculated even when represented by two cases only. Variables included in the model were marital status (never married versus ever married), socio-economic status (SES; three levels, based on broad occupational categories), age at death (continuous). Risks were calculated within the four race/gender groups by comparing each industry or occupation or exposed category to the rest of the study population as the reference. ORs and 95% confidence intervals (95% C.I.) were calculated with the Wald method using the GMBO program in the Epicure software package [Preston et al., 1990].

RESULTS

Table I shows the number of cases and controls by race and gender, along with average age at death. African-American men and women were significantly younger at death from CNS cancer than whites (men: $t = 58.9$; $P <$

TABLE II. Association of Selected Covariates and Cancer of the Central Nervous System in Study of Death Certificates in 24 U.S. States, 1984–1992

	African-American women OR 95% C.I.	African-American men OR 95% C.I.	White women OR 95% C.I.	White men OR 95% C.I.
Marital status (never married vs. ever married)	0.7 (0.6–1.0)	0.6 (0.5–0.7)	0.7 (0.6–0.8)	0.5 (0.5–0.6)
Socioeconomic status				
Low	1.0 —	1.0 —	1.0 —	1.0 —
Medium	0.9 (0.8–1.1)	1.3 (1.1–1.6)	1.1 (1.1–1.2)	1.3 (1.3–1.4)
High	1.6 (1.2–2.1)	2.1 (1.6–2.9)	1.8 (1.7–1.9)	1.8 (1.7–1.9)

0.0001; women: $t = 39.6$; $P < 0.0001$). Also, in both race groups, average age at death among male CNS cancer cases occurred 3 years earlier than the female cases (African Americans: $t = 20.6$; $P < 0.0001$; whites: $t = 79.5$; $P < 0.0001$). Never having been married showed a significant protective effect on CNS cancer risk, with ORs ranging 0.5–0.7 among the four study groups (Table II). Risk of CNS cancer increased significantly with increasing SES level in all study subgroups.

Risks were calculated for 354 industry codes and 377 occupation codes. Only industries and occupations with at least one race/gender group with a statistically significant elevated OR for CNS cancer are reported in Tables III and IV.

Industries

A significant increase in CNS cancer risk was observed for 50 industries (14%), and 30 (74%) showed gender consistency among whites (Table III). Among these, agricultural activities showed significantly increased risks among white men and women. However, risk was below 1.0 for African American men and women in crop production, while African American men employed in raising livestock showed an increased CNS cancer risk, consistent with the results among whites. Other industries showing a consistently increased risk by gender among whites included the following manufacturing industries: yarn, thread and fabric apparel and accessories, except knit; pulp, paper, and paperboard mills; printing, publishing, except newspapers; petroleum refining; leather tanning and finishing; manufacture of household appliances; electrical machinery, equipment, and supplies; motor vehicles and motor vehicles equipment; guided missiles, space vehicles and parts; cycles and miscellaneous transportation equipment; and scientific and controlling instruments. A consistent risk increase by race and gender was also observed for transportation, communications and other public utilities, such as air transportation, telephone utilities, and electric utilities; for wholesale of motor vehicles and equipment, and petroleum products, and in a few trade and service industries, including hardware stores, department stores, auto and home supply

stores, household appliances, TV and radio stores; offices of physicians; offices of dentists; health services not elsewhere classified; legal services; elementary and secondary schools; colleges and universities; and religious organizations. Race consistency was found in 19/30 industries with increased CNS cancer risk among men, and in 12/18 among women.

Occupations

Occupations showing at least one significant increase in CNS cancer risk among the four study groups were 51 (13.5%). They are listed in Table IV. CNS cancer risk was increased among secondary school teachers; administrators, education, and related fields; and knitting and weaving machine operators in all study groups. Librarians, social workers, and child care workers showed significantly elevated ORs in all three study groups for which risk was calculated. Risk was also increased for students among all study groups but white women, and for elementary school teachers among all study groups but African American men. A consistent increase in CNS cancer risk was also observed for clergy, telephone operators, typesetters and compositors, and textile cutting machine operators, for which risk estimates were available in 3/4 study groups. Occupations showing at least one significant increase in risk in the four study groups were less numerous among managerial and professional specialty occupations ($n = 13$), and technical, sales and service occupations ($n = 16$), than among occupations involved in production activities, including farming; precision production, craft and repair occupations; and operators, fabricators and laborers ($n = 21$; students are not included in these groups). Among whites, CNS cancer risk manifested a 60% consistency by gender (26/43). Race consistency was greater among women (15/19; 79%), than among men (9/19; 47%).

Job-Exposure Matrices

We applied job-exposure matrices for six potential risk factors for CNS cancer to the occupation/industry combinations of each study subject, in order to evaluate their

TABLE III. CNS Cancer Case-Control Study Based on 24 U.S. States Death Certificates: Industries with a Significant Increase in Risk by Gender and Race Subgroups*

Census code industry	African-American women cases OR (95% C.I.)			White women cases OR (95% C.I.)			African-American men cases OR (95% C.I.)			White men cases OR (95% C.I.)		
010—Agricultural production, crops	6	0.4	(0.2–0.9)	37	1.6	(1.1–2.3)	35	0.7	(0.5–1.0)	710	1.3	(1.2–1.4)
011—Agricultural production, livestock	0	—	—	12	1.6	(0.8–3.0)	2	1.4	(0.3–6.7)	228	1.5	(1.3–1.7)
101—Dairy products	0	—	—	7	1.3	(0.6–3.1)	0	—	—	61	1.3	(1.0–1.7)
142—Yarn, thread and fabric mills	12	2.9	(1.4–6.2)	252	1.1	(1.0–1.3)	27	1.7	(1.1–2.6)	264	1.1	(1.0–1.3)
151—Apparel and accessories, exc. knit	13	2.0	(1.0–4.0)	161	1.4	(1.1–1.6)	5	2.2	(0.7–6.8)	33	1.1	(0.7–1.6)
160—Pulp, paper, and paperboard mills	0	—	—	24	1.4	(0.9–2.2)	1	—	—	143	1.3	(1.1–1.6)
171—Newspapers publishing and printing	0	—	—	27	0.9	(0.6–1.4)	5	3.1	(0.9–10.9)	90	1.4	(1.1–1.8)
172—Printing and publishing, exc. newspapers	1	—	—	61	1.1	(0.8–1.4)	4	1.2	(0.4–3.9)	141	1.2	(1.0–1.4)
192—Industrial and miscellaneous chemicals	2	2.7	(0.5–16.5)	16	0.9	(0.5–1.6)	7	1.9	(0.7–4.7)	115	1.1	(0.9–1.3)
200—Petroleum refining	0	—	—	10	1.3	(0.6–2.8)	1	—	—	60	1.4	(1.1–1.9)
220—Leather tanning and finishing	0	—	—	5	7.4	(1.8–31.0)	2	8.8	(0.8–99.3)	9	2.4	(1.1–5.5)
160—Office and accounting machines	0	—	—	7	1.0	(0.5–2.4)	1	—	—	34	1.5	(1.0–2.2)
340—Household appliances	1	—	—	16	1.1	(0.7–2.0)	2	2.1	(0.4–11.4)	58	1.4	(1.0–1.8)
342—Electrical machinery, equipment and supplies	2	0.8	(0.2–3.5)	64	1.1	(0.8–1.4)	4	1.6	(0.5–5.0)	136	1.2	(1.0–1.5)
351—Motor vehicles and m.v. equipment	4	2.7	(0.7–9.5)	55	1.4	(1.0–1.9)	15	1.2	(0.7–2.1)	296	1.1	(1.0–1.2)
362—Guided missiles, space vehicles and parts	0	—	—	4	1.3	(0.4–4.0)	1	—	—	52	2.3	(1.6–3.3)
370—Cycles and mix transportation equipment	0	—	—	3	1.1	(0.3–3.8)	0	—	—	11	2.1	(1.0–4.4)
371—Scientific and controlling instruments	1	—	—	10	1.9	(0.9–4.2)	1	—	—	23	1.6	(1.0–2.6)
392—Not specified manufacturing industries	10	2.8	(1.2–6.3)	103	0.9	(0.7–1.1)	14	1.0	(0.5–1.7)	331	1.0	(0.9–1.1)
412—U.S. Postal Service	4	1.5	(0.5–4.8)	41	1.2	(0.9–1.8)	12	0.9	(0.5–1.8)	176	1.1	(0.9–1.3)
421—Air transportation	0	—	—	20	1.7	(1.0–2.9)	2	0.8	(0.2–3.9)	97	1.4	(1.1–1.8)
441—Telephone (wire and radio)	2	1.4	(0.3–7.1)	103	1.1	(0.9–1.4)	3	1.2	(0.3–4.6)	140	1.2	(1.0–1.5)
460—Electric light and power	1	—	—	19	1.5	(0.9–2.5)	2	1.1	(0.2–5.8)	159	1.4	(1.1–1.6)
500—Motor vehicles and equipment	0	—	—	4	2.1	(0.6–7.4)	0	—	—	22	1.5	(0.9–2.5)
530—Machinery, equipment and supplies	0	—	—	17	1.2	(0.7–2.0)	1	—	—	99	1.1	(0.9–1.4)
542—Apparel, fabrics, and notions	0	—	—	1	—	—	0	—	—	12	3.0	(1.4–6.5)
552—Petroleum products	0	—	—	17	1.6	(0.9–2.8)	0	—	—	61	1.3	(1.0–1.8)
581—Hardware stores	0	—	—	8	1.5	(0.7–3.5)	1	—	—	42	1.4	(1.0–2.0)
591—Department stores	6	1.7	(0.7–4.4)	186	1.3	(1.1–1.5)	6	2.1	(0.8–5.8)	62	1.3	(1.0–1.7)
612—Motor vehicle dealers	0	—	—	19	1.1	(0.7–1.9)	9	3.3	(1.4–8.1)	147	0.9	(0.7–1.1)
620—Auto and home supply stores	1	—	—	6	1.2	(0.5–3.0)	1	—	—	71	1.4	(1.0–1.8)
630—Apparel and accessories stores, exc. shoe	1	—	—	89	1.6	(1.3–2.1)	0	—	—	30	1.0	(0.7–1.5)
632—Furniture and home furnishings stores	1	—	—	26	1.9	(1.2–3.0)	2	1.6	(0.3–8.0)	56	1.0	(0.7–1.3)
640—Household appliances, TV & radio stores	1	—	—	11	1.4	(0.7–2.9)	0	—	—	57	1.7	(1.2–2.3)
652—Book and stationery stores	1	—	—	13	2.1	(1.1–4.2)	0	—	—	10	0.8	(0.4–1.6)
691—Not specified retail trade	4	5.1	(1.1–23.6)	139	1.2	(1.0–1.5)	6	4.4	(1.4–14.0)	92	1.0	(0.8–1.3)
700—Banking	1	—	—	134	1.5	(1.2–1.9)	2	3.5	(0.5–26.0)	97	1.0	(0.8–1.3)
710—Security, and investment companies	0	—	—	10	1.1	(0.5–2.3)	3	15.1	(1.5–157)	49	1.3	(0.9–1.8)
711—Insurance	2	0.7	(0.2–3.5)	124	1.2	(1.0–1.5)	4	1.3	(0.4–4.4)	222	1.0	(0.9–1.2)
712—Real estate	3	2.6	(0.6–11.7)	123	1.1	(0.9–1.3)	5	0.8	(0.3–2.2)	148	0.8	(0.6–0.9)
780—Barber shops	0	—	—	0	—	—	4	5.8	(1.3–25.9)	48	1.5	(1.1–2.1)
812—Offices of physicians	1	—	—	65	1.2	(0.9–1.6)	1	—	—	95	1.4	(1.1–1.8)
820—Offices of dentists	1	—	—	31	1.5	(1.0–2.4)	0	—	—	47	1.7	(1.2–2.4)
840—Health services, n.e.c.	2	0.6	(0.1–2.6)	56	1.1	(0.8–1.5)	1	—	—	35	1.5	(1.0–2.3)
841—Legal services	1	—	—	60	1.4	(1.0–1.9)	1	—	—	75	1.1	(0.9–1.5)
842—Elementary and secondary schools	58	1.4	(1.0–2.0)	919	1.5	(1.4–1.7)	27	1.1	(0.7–1.7)	366	1.1	(1.0–1.3)
850—Colleges and universities	6	1.1	(0.4–2.8)	113	1.4	(1.1–1.8)	9	1.6	(0.7–3.6)	189	1.6	(1.3–1.9)
880—Religious organizations	5	1.7	(0.6–5.0)	69	1.8	(1.3–2.3)	11	1.0	(0.5–2.1)	154	1.5	(1.3–1.9)
922—Administration of human resources programs	6	5.1	(1.4–18.4)	51	1.6	(1.1–2.2)	2	0.4	(0.1–2.0)	40	1.5	(1.0–2.1)
931—Administration and economic programs	0	—	—	30	1.3	(0.9–2.0)	3	3.3	(0.6–16.7)	79	1.2	(0.9–1.5)

*exc. = except; m.v. = motor vehicles; n.e.c. = not elsewhere classified; OR = odds ratio; 95% C.I. = 95% confidence interval.

TABLE IV. CNS Cancer Case-Control Study Based on Death Certificates from 24 U.S. States: Occupations with a Significant Increase in Risk by Gender and Race Subgroups*

Census Code occupation	African-American women cases OR (95% C.I.)			White women cases OR (95% C.I.)			African-American men cases OR (95% C.I.)			White men cases OR (95% C.I.)		
014—Administrators, education and related fields	5	3.3	(0.9–12.9)	33	1.2	(0.8–1.8)	4	1.3	(0.3–4.9)	3	1.4	(1.0–1.9)
055—Electrical and electronic engineers	0	—	—	2	0.9	(0.2–4.4)	1	—	—	126	1.4	(1.1–1.8)
065—Operations and systems researchers and analysts	1	—	—	3	1.0	(0.3–3.9)	0	—	—	22	2.0	(1.1–3.4)
084—Physicians	0	—	—	9	1.1	(0.5–2.3)	0	—	—	113	1.4	(1.1–1.8)
085—Dentists	0	—	—	4	5.2	(0.9–28.3)	0	—	—	42	1.6	(1.1–2.4)
154—Postsecondary teachers, subject not specified	1	—	—	22	2.0	(1.2–3.5)	1	—	—	51	1.6	(1.1–2.2)
156—Teachers, elementary school	29	1.4	(0.8–2.4)	535	1.3	(1.2–1.5)	7	0.9	(0.4–2.4)	153	1.1	(0.9–1.3)
157—Teachers, secondary school	3	4.1	(0.7–24.9)	58	1.4	(1.0–1.9)	3	5.1	(0.5–51.3)	47	1.3	(0.9–1.8)
164—Librarians	1	—	—	42	2.0	(1.4–2.9)	0	—	—	8	3.6	(1.4–9.3)
174—Social workers	10	4.2	(1.8–10.0)	42	1.5	(1.0–2.1)	1	—	—	22	1.1	(0.7–1.7)
176—Clergy	1	—	—	8	2.5	(1.0–5.6)	11	1.1	(0.5–2.3)	138	1.7	(1.4–2.0)
186—Musicians and composers	2	2.1	(0.4–11.8)	16	2.0	(1.1–3.7)	0	—	—	21	0.8	(0.5–1.3)
187—Actors and directors	0	—	—	7	5.8	(1.9–18.4)	0	—	—	4	0.7	(0.2–1.9)
216—Engineering technicians, n.e.c.	0	—	—	6	0.9	(0.4–2.1)	0	—	—	40	1.8	(1.2–2.6)
217—Drafting occupations	0	—	—	4	0.8	(0.3–2.4)	1	—	—	50	1.6	(1.1–2.2)
223—Biological technicians	0	—	—	4	1.3	(0.4–3.9)	0	—	—	50	1.6	(1.1–2.2)
243—Supervisors and proprietors, sales occupations	4	3.1	(0.9–11.1)	214	1.3	(1.1–1.5)	9	1.0	(0.5–2.2)	677	1.1	(1.0–1.3)
274—Sales workers, other commodities	6	1.8	(0.7–4.7)	298	1.3	(1.1–1.4)	6	2.2	(0.8–6.3)	151	0.9	(0.8–1.1)
313—Secretaries	4	1.5	(0.5–4.7)	662	1.6	(1.4–1.7)	0	—	—	7	0.9	(0.4–2.0)
337—Bookkeepers, accounting, and auditing clerks	2	3.0	(0.5–17.8)	249	1.4	(1.2–1.6)	0	—	—	18	0.7	(0.4–1.2)
348—Telephone operators	3 cases/0 controls			72	1.2	(1.0–1.6)	0	—	—	5	1.4	(0.5–3.7)
355—Mail carriers, postal service	0	—	—	7	2.0	(0.8–5.1)	2	0.9	(0.2–4.2)	77	1.3	(1.0–1.6)
363—Production coordinators	0	—	—	6	1.4	(0.5–3.5)	1	—	—	31	1.7	(1.1–2.7)
379—General office clerks	2	0.5	(0.1–2.7)	221	1.3	(1.1–1.5)	2	0.7	(0.1–3.1)	87	1.1	(0.8–1.3)
389—Administrative support occupations, n.e.c.	0	—	—	39	1.6	(1.1–2.3)	0	—	—	21	2.0	(1.2–3.4)
453—Janitors and cleaners	21	2.7	(1.5–4.7)	38	0.9	(0.6–1.3)	44	0.9	(0.6–1.3)	290	1.1	(1.0–1.3)
457—Barbers	1	—	—	1	—	—	4	4.6	(1.1–18.4)	48	1.5	(1.1–2.1)
458—Hairdressers and cosmetologists	7	1.4	(0.6–3.2)	117	1.2	(1.0–1.5)	0	—	—	11	0.6	(0.3–1.1)
468—Child care workers, exc. private household	4	1.6	(0.5–5.1)	32	1.6	(1.0–2.3)	0	—	—	2	2.2	(0.4–11.5)
473—Farmers, exc. horticultural	1	0.1	(<0.1–0.8)	40	2.5	(1.7–3.8)	31	0.8	(0.5–1.1)	866	1.4	(1.3–1.5)
505—Automobile mechanics	0	—	—	1	—	—	18	1.4	(0.8–2.3)	218	1.2	(1.0–1.4)
508—Aircraft engine mechanics	0	—	—	0	—	—	0	—	—	32	1.7	(1.1–2.6)
557—Supervisors, plumbers and pipefitters	0	—	—	0	—	—	0	—	—	10	2.4	(1.1–5.4)
567—Carpenters	0	—	—	1	—	—	12	1.3	(0.7–2.4)	336	1.1	(1.0–1.3)
577—Electrical power installers and repairers	0	—	—	1	—	—	0	—	—	36	1.4	(1.0–2.1)
633—Supervisors, production occupations	1	—	—	26	0.9	(0.6–1.4)	5	0.9	(0.3–2.5)	326	1.2	(1.1–1.4)
634—Tool and die makers	0	—	—	0	—	—	1	—	—	88	1.3	(1.0–1.6)
647—Jewelers	0	—	—	12	2.3	(1.1–4.6)	0	—	—	8	0.7	(0.3–1.6)
667—Tailors	0	—	—	6	2.9	(1.0–8.0)	0	—	—	9	1.5	(0.7–3.2)
678—Dental laboratory technicians	0	—	—	2	1.2	(0.2–5.7)	0	—	—	14	2.2	(1.1–4.2)
687—Bakers	1	—	—	5	0.9	(0.3–2.2)	1	—	—	26	1.5	(1.0–2.3)
695—Power plant operators	0	—	—	0	—	—	0	—	—	15	2.1	(1.1–4.0)
709—Grinding, abrading, and polishing machine operators	0	—	—	3	2.2	(0.6–8.9)	0	—	—	32	1.5	(1.0–2.2)
736—Typesetters and compositors	2	4.2	(0.6–30.7)	4	1.3	(0.4–3.8)	0	—	—	14	2.0	(1.1–3.8)
739—Knitting, and weaving machine operators	3	6.3	(1.0–38.0)	36	1.1	(0.8–1.6)	2	4.2	(0.6–30.0)	26	1.5	(1.0–2.4)
743—Textile cutting machining operators	0	—	—	4	8.9	(1.6–48.6)	2/0 controls			4	2.8	(0.8–9.5)
744—Textile sewing machine operators	13	1.9	(1.0–3.7)	161	1.2	(1.0–1.4)	2	0.7	(0.2–3.2)	19	1.1	(0.8–1.3)
793—Hand engraving and printing occupations	0	—	—	3	2.4	(0.6–9.5)	0	—	—	3	7.1	(1.2–42.6)
796—Production inspectors and examiners	1	—	—	88	1.3	(1.0–1.7)	2	1.1	(0.2–5.5)	66	0.8	(0.6–1.0)
834—Bridge, lock and lighthouse tenders	0	—	—	0	—	—	0	—	—	5	2.8	(1.0–8.5)
915—Students	3	7.9	(1.3–49.9)	22	0.9	(0.6–1.5)	2	11.1	(1.0–128)	40	2.6	(1.8–3.9)

*For abbreviations see note on Table III.

TABLE V. CNS Cancer Case-Control Study Based on Death Certificates from 24 U.S. States: ORs Associated with Risk Factors as Assessed with a Job-Exposure Matrix by Gender and Race Groups

Risk factor	African-American women			White women			African-American men			White men		
	cases	OR	(95% C.I.)	cases	OR	(95% C.I.)	cases	OR	(95% C.I.)	cases	OR	(95% C.I.)
Electromagnetic fields	78	1.2	(0.9–1.6)	1382	1.0	(0.9–1.1)	234	1.0	(0.8–1.2)	5271	1.0	(1.0–1.0)
Solvents	47	1.2	(0.9–1.7)	825	1.1	(1.0–1.2)	172	1.1	(0.9–1.3)	3562	1.0	(1.0–1.1)
Herbicides	5	0.4	(0.1–0.9)	49	1.7	(1.2–2.4)	49	0.8	(0.6–1.1)	1004	1.3	(1.2–1.4)
Other pesticides	8	0.5	(0.2–1.1)	62	1.4	(1.0–1.8)	60	0.9	(0.6–1.2)	1079	1.3	(1.2–1.4)
Contact with animals	6	0.4	(0.2–1.0)	46	1.6	(1.1–2.2)	43	0.8	(0.6–1.1)	967	1.3	(1.2–1.5)
Contact with the public	128	1.2	(0.9–1.5)	2473	1.1	(1.1–1.2)	70	1.2	(0.9–1.6)	1941	1.0	(1.0–1.1)

association with CNS cancer (Table V). Exposure to electromagnetic fields was not associated with an elevated CNS cancer risk among men. A 25% increase in risk was observed among African-American women. Exposure to solvents was associated with a significant, though modest, increase in CNS cancer risk among white women. Risk was also showed a 8–20% increase of borderline statistical significance among African-American men and women, but not among white men.

Herbicides, other pesticides, and contact with animals showed a 30–70% increase in risk among white men and white women, but none of the ORs for these factors were above 1.0 among African-Americans. Unfortunately, we were unable to disentangle the effects of these three risk factors, as study subjects with positive exposure assignment were largely the same.

Contact with the public showed a significant increase in CNS cancer risk among white women, corroborated by similar results of borderline statistical significance among African American men and women, while risk was not increased among white men. The association was stronger in the medium SES category, with ORs ranging 1.4–2.0 among women, statistically significant in both race groups, and 1.0–1.2 among men. Risks in the low SES category (range 0.9–1.1) and high SES category (range 0.9–1.3) were inconsistent and none reached statistical significance (not shown in the tables).

DISCUSSION

In this large case-control study based on death certificates from 24 U.S. states, contact with the public at work was associated with a modest increase in CNS cancer risk in 3/4 study groups. We set and applied a job-exposure matrix for contact with the public to explore the hypothesis of a role of transmissible factors in the etiology of CNS cancer [Swenberg, 1977]. Further studies with more specific data are warranted before drawing conclusions.

Electrical and electronic industry workers also have been reported to have increased brain cancer risk [Loomis, 1990; Preston-Martin et al., 1989; Thomas et al., 1987]. This

suggested an etiologic role for exposure to electromagnetic fields (EMF). To date, the literature on EMF has been inconsistent: brain cancer excesses were reported among telephone installers and repairers [Juutilainen et al., 1990], workers in the primary aluminum industry [Milham, 1985], and commercial airline pilots [Band, 1990], but negative findings have also been published [Pearce et al., 1989; Vagero and Olin, 1983]. Results of the studies based on EMF measurements were also inconsistent [Thériault et al., 1994; Floderus et al., 1993; Savitz and Loomis, 1995]. Our study shows an increase in CNS cancer risk in a few industries and occupations related to manufacture, use, maintenance, and sale of electrical devices and telephones, as well as for air transportation. Risks were generally consistent between genders, while these occupations were seldom represented among African-American cases to evaluate race consistency in CNS cancer risk. A nonsignificant excess risk was also observed in the primary aluminum industry among white men (OR = 1.2; 95% c.i. = 0.8–4.7; data not shown in the tables). However, applying a job-exposure matrix for EMF resulted only in a 20% increase in CNS cancer risk among African-American women, and no excess among the other study groups. This lack of association contrasts with the results for some specific industries and occupations. This may indicate that the job-exposure matrix was inefficient in defining EMF exposure, because of large variation in characteristics of exposure among occupations and industries considered exposed, or that no association exists, and other exposures may be responsible for the excesses observed among some of the EMF-related occupations and industries. Our data do not provide sufficient detail to help distinguish between these alternative interpretations.

In the present study, the chemical and petrochemical industry showed some association with brain and CNS cancer. Risk was increased among white men and women in the petroleum refining industry, among white men in the miscellaneous plastic products (OR = 1.2; 95% c.i. = 0.8–1.9; not shown in the tables), and among all study groups but white women in industrial and miscellaneous chemicals production. CNS cancer risk was also increased, though not statistically significant, in tires and inner tubes

manufacturing among men, other rubber products among white women, and drug manufacturing among white men and women (data not shown in the tables). These results match published reports of excesses of brain cancer in the chemical and petrochemical industry, including polyvinyl chloride (PVC) manufacture [Tabershaw and Gaffey, 1974; Monson et al., 1974], in which exposure to the carcinogenic vinyl chloride monomer (VCM) occurs, oil refineries [Harrington, 1987; Magnani, 1987; Nicholson et al., 1982; Theriault, 1987; Thomas et al., 1982; Waxweiler et al., 1983], the asphalt industry [Hansen, 1989], and the pharmaceutical industry [Thomas and Decoufle, 1979]. However, most studies of PVC producers [Byren et al., 1977; Chiaze, 1977; Dahar et al., 1988; Pirastu et al., 1991; Wu et al., 1989] have not shown an increase in CNS cancer risk, and a meta-analysis of the petroleum industry concluded that brain cancer mortality was identical to that of the general population [Wong and Raabe, 1989]. Increased brain cancer risks have been observed among rubber workers [Monson, 1978; Delzell, 1981; Kessler and Brandt-Rauf, 1987] particularly those who started working before 1930 [Kessler and Brandt-Rauf, 1987], but some studies have found no excess [Englund et al., 1982; Negri et al., 1989; Symons et al., 1978]. Inconsistencies among results from earlier and more recent studies of the rubber industry may reflect changes in technology, and consequently in workplace exposures [Kessler and Brandt-Rauf, 1987].

Consistent with previous reports of an increased risk of brain cancer in motor vehicle manufacturing [Preston et al., 1982] and the aerospace industry [Park et al., 1990], we found a 1.3–2.3-fold increase in CNS cancer risk among white men and white women in the space industry (guided missiles), and risks ranged 1.1–2.7 among the four study groups for motor vehicle manufacturing. Excess risks were also found for auto mechanics, and tool and die makers among both groups of men. Unlike previous investigations, we found no increase in risk for firefighters [Vena and Fielder, 1987; Wallace et al., 1982], or plumbers [Cantor, 1986]. Risk for pattern makers [Robinson, 1980] was nonsignificantly increased, and risk for jewelers [Dubrow, 1987] was significantly increased among white women, but it was below 1.0 among white men.

Organic solvents [Thomas and Waxweiler, 1986; Rodvall et al., 1996], particularly chlorinated hydrocarbons [Heineman et al., 1994; Park et al., 1990] have been suggested as possibly related to the widespread, and apparently heterogeneous, array of occupations associated with increased CNS cancer risk. In the present study, potential exposure to the general category of solvents was analyzed with a job-exposure matrix, and a significant association with increased CNS cancer risk was observed only among white women. A modest non significant risk increase was also observed among both African American groups, but not among white men. Occupational exposure to solvents and EMF seems to be associated particularly with an increase in

risk of astrocytic brain tumors, the most frequent CNS tumors in adults of both genders [Heineman et al., 1994; Mack et al., 1991], while meningioma appears more frequently among women [Preston et al., 1982]. Therefore, it seems unlikely that gender-related factors account for our result. Misclassification of exposure is more likely to have diminished observed risks, because of the broad definition of “organic solvents,” the broad occupation and industry codes, and the large variation in exposure within occupations, and over calendar time.

Proportional mortality studies and case-control studies have consistently found increased brain cancer risks among agricultural occupations [Blair et al., 1992]; risks were higher limiting the analysis to gliomas [Musicco et al., 1982]. Farmers are typically exposed to a wide variety of agents, including insecticides, fungicides, herbicides, fertilizers, and potential contact with zoonotic viruses [Blair et al., 1992]. A cohort study of white male pesticide applicators in Florida showed an SMR of 2.2 for brain cancer [Pesatori et al., 1994]. A 12-fold increase in glioblastoma risk was found among Italian farmers who started farming after 1960, when the use of organic pesticides increased [Musicco et al., 1982]. Use of fungicides containing methyl-urea has received attention as a possible brain cancer risk factor in agriculture, since alkyl-ureas are carcinogenic to the brain in rats [Rajewsky and Laerum, 1977].

In the present study, agricultural industries and occupations showed increases in CNS cancer risk only among white men and women, and they were statistically significant only among men. Herbicides, other pesticides, and contact with animals were significantly associated with CNS cancer risk in white men only. We were unable to determine if any of these exposures confounded each other, since exposed individuals were largely the same in the three “exposed” groups.

Professional and intellectual activities, including medical occupations [Thomas and Waxweiler, 1986; Ahlbom et al., 1986; Hall et al., 1991; Mallin, 1989; Stroup et al., 1986; Matanoski, 1989], teachers, mathematicians, statisticians, and clergymen [Reif, 1989a], salesmen and lawyers [Mallin, 1989], engineers and artists [Thomas et al., 1986] are among the occupations most frequently reported at risk of CNS cancer. When resulting from analyses of death certificates, such excesses might be artifactual, as medical care and diagnostic procedures are likely to be more accurate for subjects in the high socio-economic levels [Finkelstein and Liss, 1987]. To account for its effect, we included SES in the logistic regression models. After adjusting for SES, we confirmed a rather consistent increase in CNS cancer risk among the intellectual, clerical, financial, commercial, health related, administrative, and managerial occupations. Results were consistent by gender and race, and with findings among industries. However, as the SES categorization was based on broad occupational groups, extent of the adjustment and precision of risk estimates are still doubtful.

What factors underlie the association between CNS cancer and having being married is unknown. Whether a greater likelihood of exposure to transmissible agents within a family could be involved, consistent with our positive finding of an association with contact with the public at work, is simply a matter of speculation.

Main limitations in this study include poor diagnostic accuracy and poor occupational information in the death certificates, which, respectively, may have caused misclassification of disease and exposure. However, if accuracy of disease and occupation reporting do not differentiate between cases and controls, a true association would be biased toward the null in a two-by-two table [Rothman, 1986]. Therefore, misclassification itself wouldn't be a valid explanation for positive findings. On the other hand, although occupational information was limited to occupation and industry reported in the death certificate of study subjects, the advantages offered by analyzing large population-based data sets are two-fold: 1) the possibility of exploring associations in a vast range of occupations and industries for which numbers are usually not sufficient in epidemiologic studies; and 2) the possibility of exploring consistency of associations by gender and race. In addition to the size and statistical significance of the ORs, a consistent risk pattern across race/gender groups may be helpful in inferring occupational associations. In our opinion, these two advantages compensate the scarce and poorly detailed information. However, analyzing a large data set also increases the number of false positive findings as a result of the number of comparisons made. Suggestions have been made to restrict proportionally the criteria for statistical significance [Rothman, 1986], but this approach would increase the likelihood of false negative findings. We searched for consistency by gender and race groups and with already published literature for *a priori* suspected industries, occupations, and potential exposures from the job-exposure matrices. Difficulties in interpreting inconsistent findings may arise when women and men, or whites and African-American, sharing the same occupational title, perform different duties and have different exposures.

In conclusion, these results confirm that several occupations are associated with an increase in CNS cancer risk. Further studies are required to investigate in more detail which specific occupational exposures are responsible for the observed associations.

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